ARM Atmospheric Radiation Measurement Program

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# ARM Facilities Newsletter

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## Soil Water and Temperature System ¾ SWATS

In the realm of global climate modeling, numerous variables affect the state of the atmosphere and climate. One important area is soil moisture and temperature. The ARM Program uses several types of instruments to gather soil moisture information. An example is the soil water and temperature system (SWATS) (Figure 1).

A SWATS is located at each of 21 extended facility sites within the CART site boundary. Each system is configured to measure soil moisture and temperature at eight distinct subsurface levels (Figure 2).

A special set of probes used in the SWATS measures soil temperature, soil-water potential, and volumetric water content. Sensors are placed at eight different depths below the soil surface, starting at approximately 5 cm (2 in.) below the surface and ending as deep as 175 cm (69 in.). Each site has two identical sets of probes buried 1 m (3.3 ft) apart, to yield duplicate measurements as a quality control measure. At some sites, impenetrable soil or rock layers prevented installation of probes at the deeper levels.

The sensors are connected to an electronic data logger that collects and stores the data. Communication equipment transfers data from the site. All of the electronic equipment is housed in a weatherproof enclosure mounted on a concrete slab.

Figure 1. A typical soil water and temperature system (SWATS) installation. The white box houses the electronics equipment and shields it from the elements.

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*Technical Contact*: James C. Liljegren *Editor*: Donna J. Holdridge

Each sensor consists of a ceramic matrix into which a hypodermic needle is inserted. A thermocouple and a resistance heater are installed inside the bore of the needle (Figure 3). Measurements are made by using heat dissipation principles. A temperature increase occurs when an

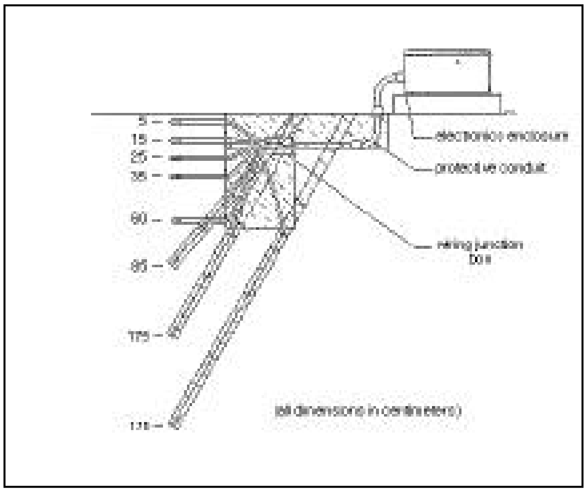


Figure 2. A cross sectional view showing the locations of SWATS probes.

electric current is directed to the resistance heater. The heat produced dissipates into surrounding water held in gaps between soil particles. The temperature rise and the heat dissipation are measured by the thermocouple inside the needle. If the gaps in the soil contain water, a large amount of heat will be dissipated, and the temperature rise will be small. If less water is in the soil gaps, or if they contain mostly air, the amount of heat dissipated will be smaller, resulting in a larger temperature rise.

A calibration curve is used to estimate the volume of water in the soil on the basis of the temperature rise and heat dissipation measured. The amount of water that soil can hold is a function of its physical makeup. Soil characteristics can vary from place to place; therefore, the soil at each SWATS site was characterized, and calibration curves were established individually.

Measurements are made once each hour. Each SWATS sensor reports the initial soil temperature (before application of the electric current), the temperature rise, the soil-water potential estimate, and the volumetric water content estimate. Soil-water potential is a measure (in units of kilopascals) of the amount of energy required to remove water from the soil particles to which it adheres. Measurements of soil-water potential can be used to determine the amount of water available in soil for plants to absorb. Soil-water potential can also be used to track the movement of water within soil layers and the amount of water that evaporates from soil. Volumetric water content describes the volume of water in a given volume of soil (cubic meters of water per cubic meter of soil).

ARM uses the Internet to monitor and check the SWATS data. An example of soil temperature and volumetric water content data is in Figure 4. Such data can be used to check on the operation of the

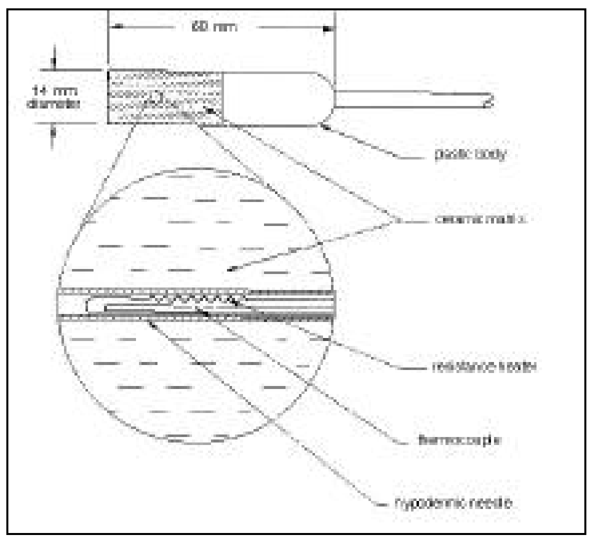


Figure 3. Schematic drawing of a SWATS probe.

instrument without physically visiting each site. This saves time and also alerts ARM staff to any unforeseen problems with the instruments between maintenance visits by ARM technicians every other week.

Figure 4 contains typical SWATS measurements. The top set of plots shows the daily variation in soil temperature. The soil temperature near the surface changes markedly at sunrise and sunset, as the warming effect of solar radiation comes and goes. The change is most dramatic closest to the surface. The lower set of plots represents the volumetric water content of the soil. After a rain event (shown in the middle panel of this set), soil water content rises in the top three levels. Subsequently, water content decreases as water evaporates and leaves the soil.

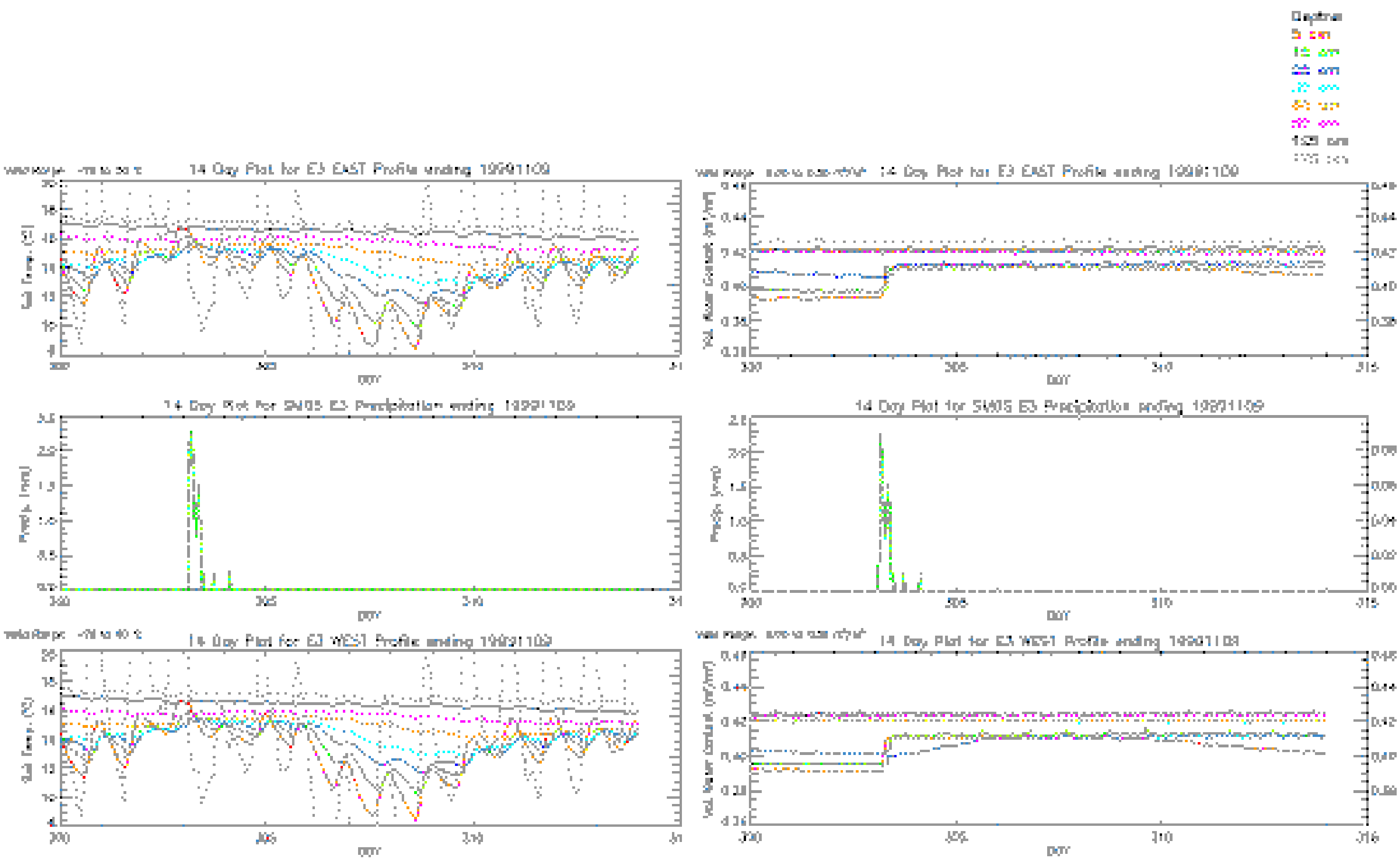

Figure 4. Sample SWATS data from LeRoy, Kansas. The top group of three panels shows soil temperature at eight depths, in addition to ambient air temperature. The bottom group shows volumetric water content of the soil at each level. The center panel of each group shows precipitation amount. Each set of plots is for a 14-day period.